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PHOTO ACTIVATED DISINFECTION IN DENTISTRY

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ABSTRACT

Photodynamic theory can be defined as eradication of target cells by reactive oxygen species produced by means of a photosensitizing compound and light of an appropriate wavelength. Photo activated disinfection is indicated for the disinfection of all types of tooth decay (carious) lesions, of fissures before sealing and in the disinfection of root canals.

KEYWORDS: A photosensitizing compound and light of an appropriate wavelength.

INTRODUCTION

Dental caries is a disease that initially demineralizes the enamel and then progresses slowly into the dentin. The advancing zone of demineralization is preceded by a layer of partially demineralized dentin infected with bacteria.[1] During clinical evaluation and/or treatment, it is difficult to differentiate these two zones and as a result, significant quantities of sound but demineralized tooth tissue are removed during cavity preparation.

However, it is conservatively advantageous to retain the partially demineralized dentin, but only if the bacteria can be reliably eliminated. There are two possible approaches to conserving remaining sound tooth structure:

1. The use of bacterial detection agents that assist in the removal of the infected (and only the infected) tissues.
2. The use of photo-activated disinfection to eliminate bacteria and then to remineralize the partially infected dentin.

As high levels of bacteria are present in the oral environment, even cavities freshly prepared to the level of sound tooth structure still have microorganisms in the dentinal tubules and enamel lattices. Hence photo-activated disinfection can be used to disinfect any tooth type.[2-4]

WHAT IS PHOTO ACTIVATED DISINFECTION (PAD)

Photo-Activated Disinfection is an innovative technology that utilizes two non-toxic components, a photo-activating liquid and an LED light source to selectively tag and destroy cariogenic bacteria and periodontal pathogens.

Photo-Activated Disinfection involves three components: light, a photosensitizer, and oxygen. A photosensitizer or its metabolic precursor is administered to the patient. Upon irradiation with light of a specific wavelength, the photosensitizer undergoes a transition from a low-energy ground state to an excited singlet state. Subsequently, the photosensitizer may decay back to its ground state, with emission of fluorescence, or may undergo a transition to a higher energy triplet state. The triplet state reacts with endogenous oxygen to produce singlet oxygen and other radical species, causing a rapid and selective destruction of the target tissue.[5,6]

HISTORY

The concept of treatment with light and photoactive compounds can be traced back over 6000 years to the ancient Egyptians who used light-sensitive substances (psoralens) by crushing leaves of plants related to parsley with sunlight to treat sunburns. Reference to the use of a plant extract for the restoration of skin pigmentation was made in 1400 BC and phototoxic effects of psoralens were described in 1250 AD.[7] Ancient Indians also believed that vitiligo could be treated by the combination of extracts of Psoraleacorylifolia and light. But the actual breakthrough came by Finsen's pioneering research in 1901 in which he showed that skin tuberculosis could be successfully treated with natural and artificial ultraviolet light.

The first medical use of chemically enhanced phototherapy (other than for restoration of pigmentation) was reported by Jesionek and Tappeiner in 1905 when they treated five basal cell carcinomas by injecting eosin into the tumor and exposing it to light reporting three cures.

The essential involvement of light and oxygen in the process was shortly thereafter demonstrated by Tappeiner,[8] who coined the term 'photodynamic'. Haxthausen and Hausmann in 1908 were the first to suggest that hematoporphyrin was a photodynamic photosensitizer. In 1960, Theodore Maiman, a scientist with the Hughes Aircraft Corporation, developed the first working laser device which emitted a deep red colored beam from a ruby crystal (Coluzzi, 2004). Wilson et al. (1993) proved the effect of cyanide photosensitizer on Gram-negative and Gram-positive species. Ackrayd (1999) used aminolevulinic acid-induced PDT for treatment of adenocarcinoma.

MECHANISM OF ACTION

Photosensitization is a treatment that involves the interaction of two non-toxic factors, such as a photo-active compound (tolonium chloride) and a directly applied visible light (LED illumination at 635nm).[9,10] They form metachromatic complexes with lipopolysaccharides that can be photo-activated to cause oxygen ion release.[11] The oxygen ions are specifically toxic to a vital structural component of the target cells.[12,13] Photo-Activated Disinfection requires a source of light that activates the photosensitizer by exposure to low-power visible light at a specific wavelength. Most photosensitizers are activated by red light between 630 and 700 nm, corresponding to a light penetration depth from 0.5 cm (at 630 nm) to 1.5 cm (at ~ 700 nm).[14]

Bacterial cells are typically composed of a variety of cytoplasm materials enclosed by a cell wall. Many "traditional" anti-microbial substances must enter and accumulate inside the bacterium in order to destroy their targets. Since this process requires a transport mechanism through the cell wall, it gives the bacteria an opportunity to build up a resistance by modifying the transport mechanism required by the drug. This also applies to photo-activated drugs that must accumulate within the cell.[15]

Certain photoactive agents are taken up by bacteria preferentially, with the agent residing in the proximity of or becoming attached to the cell wall. Some may even enter microorganisms. All bacteria have the potential to be targeted, though some combinations between certain sensitizers and certain organisms are more successful than others. Healthy human tissue will not be affected.

PAD techniques use low power lasers to elicit a photochemical reaction in a photosensitizer, which in turn exerts a lethal effect on particular cells, such as bacteria. PAD is basically a lethal laser photosensitization. Photosensitizers alone in the right doses are not toxic to bacteria. Low power (diode) laser energy in itself is, again, not particularly lethal to bacteria but is useful for photochemical activation of oxygen-releasing dyes. Singlet oxygen, a protoplasmic poison released from dyes, causes lethal membrane, organ and DNA damage to microorganisms.[5]

PHOTO ACTIVATED DISINFECTION APPLICATIONS IN DENTISTRY

Photo activated disinfection is indicated for the disinfection of all types of tooth decay (carious) lesions, of fissures before sealing, and in the disinfection of root canals. In carious lesions, the bulk of the infected dentine or enamel is removed by either hand instrument or where deeper cavities exist, a minimally invasive drill. Some disinfected demineralized tissue can be left before PAD is administered. In root canals, PAD is administered to disinfect the area before immediate endodontic restoration, taking one session rather than the two of conventional dental treatments. PAD has several applications in dentistry.

Endodontic treatment

The success of endodontics is directly influenced by the elimination of microorganisms in infected dental root canals. It is well known that microorganisms colonizing in oral environment can be conducive to pulpal and periapical pathosis. The purpose and ultimate goal of endodontics is to eliminate the bacterial infection in the dental root canal system and allow healing of apical periodontitis. Primary root canal therapy is a highly predictable procedure; however the inability to sufficiently disinfect the dental root canal system may lead to failure of root canals treatments or persistent apical pathosis (Ercan et al, 2006) in addition to killing bacteria lasers cause collateral damage such as charring of dentin, ankylosis of root, melting of cementum, root resorption, and periradicular necrosis.

However PAD does not increase the temperature above 7^{o} C which was within the safety level for periodontal injury. So use of PAD in root canals could be considered harmless for periodontal tissues also.[16,17] PDT has shown to be effective against Gram positive as well as Gram-negative endodontic pathogens like Enterococcus faecalis, Streptococcus intermedius, Fusobacterium nucleotum, Pepto streptococcus micros, Prevotella intermedia.[18,19]

Dental Caries

Research has recently demonstrated that photo-sensitized cariogenic bacteria can be killed by directly applied visible light.[2,20,4] The technique involves applying a photo-active solution that is absorbed selectively by cariogenic bacteria to the operative surfaces. This sensitizes them to the application of visible illumination which causes cytotoxic bacterial reactions that result in selective destruction of the target microorganism.[21]

Periodontal therapy

Scaling and root planning can remove the calculus and plaque but has little effect on the acidogenic and aciduric bacteria that is the cause of these deposits and the ensuing periodontal disease that has been associated with numerous systemic health problems. Research has indicated that an identical PAD mechanism functions to combat the bacteria that are largely responsible for periodontitis like porphyromonas gingivalis,

Actinobacillus actinomycetem comitans, Fusobacterium nucleatum, Streptococcus sanguinis, Bacteroides forsythus, Campylobacter rectus and Eikenella corrodens.[22,23]

OTHER APPLICATIONS OF PAD

Photodynamic Antimicrobial Chemotherapy (PACT) represents an alternative antibacterial, antifungal and antiviral treatment for drug resistant micro-organisms. It is unlikely that bacteria would develop resistance to the cytotoxic action of singlet oxygen or free radicals. Applications of PAD are growing rapidly in the treatment of oral cancer, bacterial, fungal infections and diagnosis of malignant transformation.[5]

CONCLUSION

In PAD treatment, the remaining tooth surfaces are disinfected and thus are far more likely to remineralize effectively. Patients and practitioners have had understandable qualms about the level of disinfection that can be practically and realistically achieved during routine dental procedures. Given the high levels of ambient bacteria in the oral cavity and the difficulty of isolating surgical treatment sites during and after procedures, it is evident that additional disinfection modalities are welcome additions to the dental armamentarium.

Photo-activated disinfection offers a heightened level of disinfection during and after operative and periodontal procedures (in addition to endodontic and peri-implant treatments that were not discussed above). A relatively rapid and simple procedure which is readily inserted into the treatment routine, Aseptim Plus destroys bacteria both on the surface and underneath to provide healthier periodontal tissues and more predictable and longer lasting restorative interfaces.

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